CONSTRUCTIONS OF THE SHIP-IMPACT PROTECTIVE DOLPHIN IN INCHEON BRIDGE PROJECT

Byung-Sun Kim
Assistant Manager
Samsung C&T Corporation
byungsunkim@samsung.com

Yu-Suk Son
Deputy General Manager
Samsung C&T Corporation
handson@samsung.com

Dong-Wan Kim
General Manager
Samsung C&T Corporation
wallgye@samsung.com

Hwa-Soo Kim
Vice President / PM
Samsung C&T Corporation
hs01kim@samsung.com

Sung-Min Cho, Ph.D.
TA Team Leader
Incheon Bridge Construction Office, Korea Expressway Corporation
chosmin@ex.co.kr

Abstract: *Incheon Bridge was designed to protect the bridge against the collision with navigation vessels. Large diameter circular dolphins are constructed at 44 locations of the both side of the main span around the piers of the cable stayed span. Each dolphin structure consists of the flat sheet piled wall and in-filled aggregates to absorb the collision impact.These 44 dolphins of Incheon Bridge had to be constructed within 18 months. To achieve the erection within the assigned period, the templates were managed in 3 groups. The assembled cells weigh 1000ton with diameter of 20 and 25m and, height of 38m. Main process of the construction is summarized.*

Keywords: sheet pile, template, circular cell, ship impact protection, crane, Incheon Bridge

1. SHIP IMPACT PROTECTION SYSTEMS OF THE INCHEON BRIDGE

Incheon Bridge was designed to protect the bridge against the collision with navigation vessels. Circular cell structures as ship-impact protective dolphins are constructed at 44 locations of the both side of the main span around the piers of the cable stayed span (Figure 1). 44 circular-cell type dolphins surround the piers near the navigation channel to protect the bridge against the collision with aberrant vessels. Each dolphin structure consists of the flat sheet piled wall and in-filled aggregates to absorb the collision impact. Geo-centrifugal tests were already performed to evaluate the behavior of the dolphin in the seabed and to verify the numerical model for the design.
Figure 1 shows the alignment of dolphins. In compliance with the agreements for the project and related specifications, these dolphin type SIP systems should protect the Incheon Bridge against the collision with 100,000 DWT tanker navigating the channel with speed of 10 knots. Diameter of the dolphin is 25 m, or 20 m according to its location. Navigable passage width for main channel is 625.5 m under the main span deck of the cable stayed bridge and 140 m for auxiliary channel at side span behind the pylon.
Construction procedures of the ship-impact protective dolphins are shown in Figure 2 and they are introduced in the following articles.

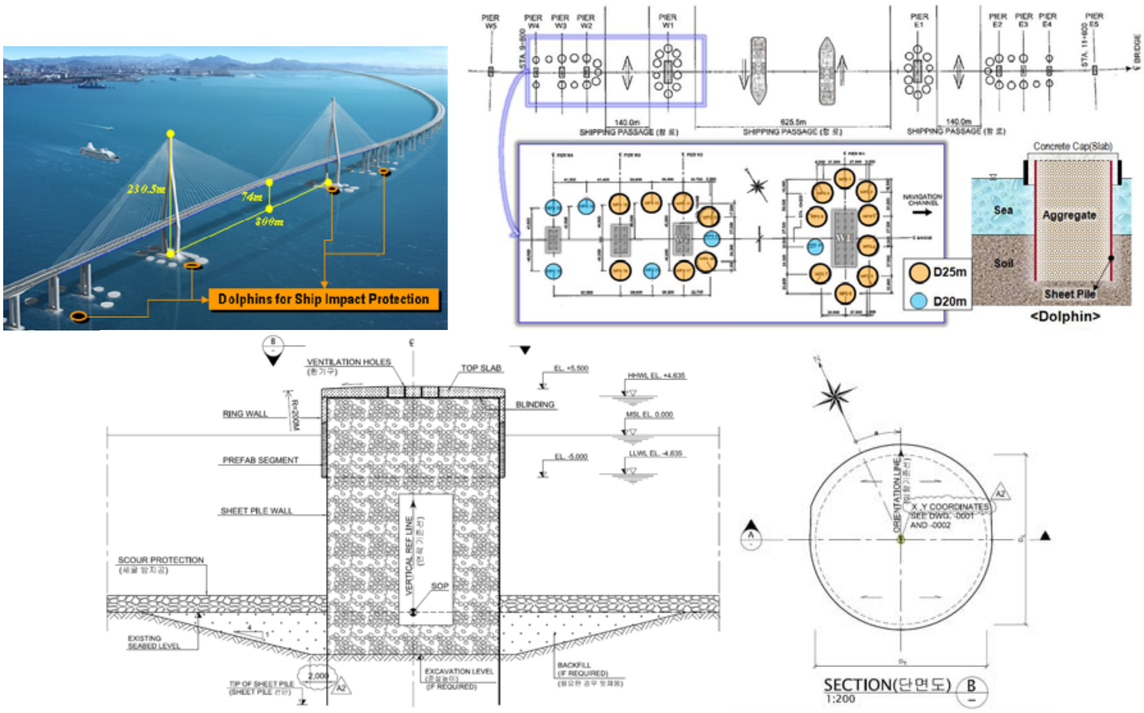

Figure 1 : Layout and cross-section of the dolphins

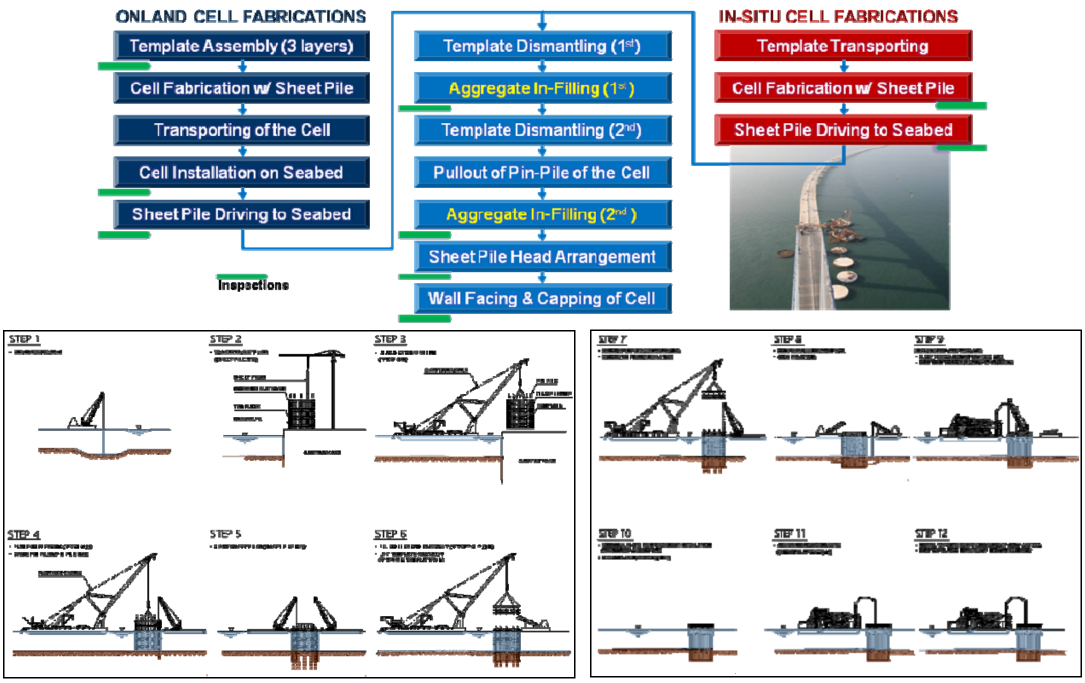

Figure 2 : Construction Procedures of the Celluar Dolphin

2. CONSTRUCTION SCHEDULES

Twelve days are necessary for the onshore assemblage of one cell of the ship impact protective dolphin. The detailed schedule proceeds as follows. First, five days are dedicated for the installation of the template and pin piles to maintain the geometry of the cell structure and for the joint welding process.

Then, one day is spent to install the working platform for the workers who will connect the sheet piles. Since about 40 sheet piles are assembled per day, approximately four days are required to complete the assemblage of the whole set of sheet piles (158 piles). Finally, two supplementary days are needed to install the channel for the electric anti-corrosion system of the sheet piles and apply the anti-rust coating. These two days also include the welding of sets of 3 sheet piles executed to reduce the construction period during the offshore driving of the piles.

Figure 3 : Template Assembly to Fabricate the Cell in the Casting Yard

Table 1 : Construction Tolerances of the Dolphin

Types	Inclination	Location	Top Elevation	Tip Elevation	Diameter	Angle
Sheet Pile	[Land] 1/150 [In-situ] 1/100	-	±50 mm	±300 mm	±100 mm	
Dolphin	1/75	±300 mm	±100 mm	-	±200 mm	±1°

A roll up jig was used to reduce the working time during the onshore assemblage of the ship impact protection. The roll up jig is a working frame enabling to erect several sheet piles (3 piles) at once. In general, since the sheet piles exhibit thin thickness (12.7 mm) and length of 38 m per pile, significant flexure may occur during their hauling by the crane. The roll up jig was adopted to prevent such bending. In addition, 3 levels of surface plates (4 per level) at the middle of the template should be dismantled in advance for the pulling by the floating crane (3000 tonf) after the completion of the cell assembling. The dismantlement of the surface plates shall be done as fast as possible to allow the floating crane to move to a position with sufficient water depth before the ebb tide considering the tidal difference of 9 m in Incheon. Since there are few goliath floating cranes in Korea, the non-respect of this condition will provoke damages of the bottom of the floating crane and have extreme effect on the whole construction progress. Accordingly, the surface plates were dismantled within one hour by using the same method applied for the dismantlement of the mast of tower cranes.

The 44 cellular dolphins of Incheon Bridge had to be constructed within 18 months. To achieve the erection within the assigned period, the templates were managed in 3 groups. This enabled to install 2 units per month. Among them, the cells below the large blocks of the steel deck could not be erected using the floating crane. Accordingly, the erection of these cells was planned by using a jack-up barge. In addition, differently from the monolithic templates adopted for Seohae Bridge and Shihwa Tidal Power Plant, the dismantlement method per level was applied for the templates of Incheon Bridge. The monolithic method allows installation in areas exhibiting regular water depth but requires long working periods. On the other hand, the dismantlement method per level can be used exclusively and enables to achieve reduction of construction costs. This method is also applicable in areas with extremely irregular water depth such as the site of Incheon Bridge.

3. CONSTRUCTIONS

The assembled cells weigh 1000 tonf with diameter of 20 and 25m and, height of 38 m. The weight and height of the cranes for the assemblage of the cells and the erection of the ship impact protection is 9,632 tonf and 95.4 m for the 3,000 tonf crane, 6,944 tonf and 80 m for the 2,000 tonf crane, and 1,222 tonf and 54 m for the 450 tonf crane. When the assembled cell is transported offshore, the cell is pulled by the 3000 tonf floating crane (Figure 4). During the transport, attention should be paid on avoiding limitation to the passage of the barge. Since Incheon Harbour is visited yearly by more than 40,000 ships with the largest ship reaching 100,000 tonf, need is to take care of the navigational traffic.

Figure 4 : Transportation of the Cell (Dolphin) from the Casting Yard to the Installation Site

Accordingly, for the Incheon Bridge site, once the installation schedule of the cells was decided, a preliminary visit to the control room of Incheon Harbour was done to arrange and tune the issues and occupied zones with regard to the traffic schedule in the main navigational channel. Thereafter, two tugboats (3600HP) were used to pull the cells offshore at speed of 5knot and maintain them at the surface. A safety patrol boat also accompanied the tugboats to the installation site to prevent the eventual occurrence of safety accident with neighbouring ships.

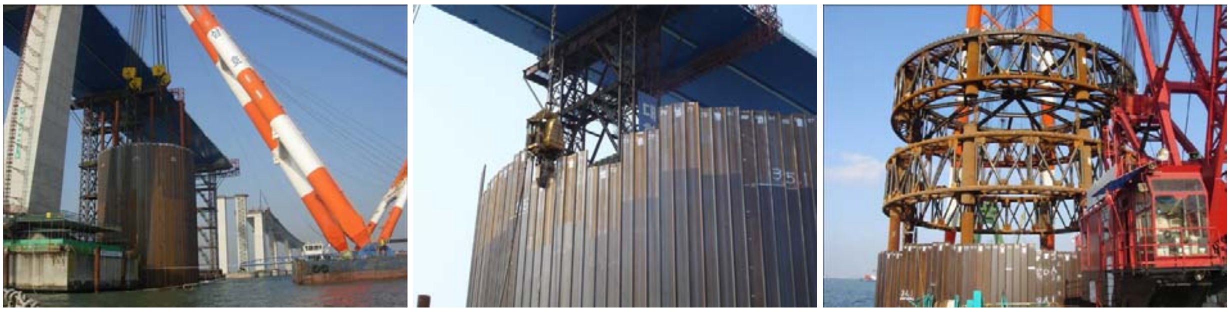

Figure 5 : Dolphin Installations on the Seabed

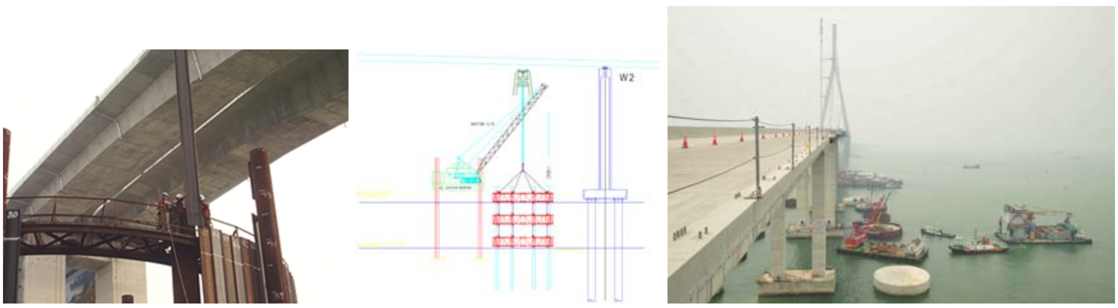

Figure 6 : Cell Fabrications in the Offshore Site not to Interfere the bridge constructions

The offshore installation process of the assembled cells proceeded by installing the anchors of the 3000 tonf floating crane using the anchor boat. Then, setting was executed at the exact position by means of measurement equipment (white target TS). The setting time of the cells was performed at the ebb tide to minimize at the most the effects of the tidal current. This task was extremely precise in view of the installation error of ±300 mm

After minute adjustment through measurement and setting to the exact position, the cell was descended down to the seabed. Thereafter, two floating cranes that were on standby were moved to the cell structure. A lift car was then prepared and the workers boarded on the car to be moved inside the cell. The pin piles (8 piles) were free fallen by oxy-acetylene cutting and driven to the design depth by connecting them to a vibro-hammer installed on a 180 tonf floating crane. The sheet piles were also free fallen using oxy-acetylene cutter simultaneously to this work. After the driving of the pin piles, the cells were pulled up to the design height. Then, check was done to verify if the top of the templates was horizontal and the templates were fixed using steel bars. At that time, the pin plate and template guidepile were welded by plates to secure structural stability. Finally, the equipment was removed (welding machine, cutter) and the personnel was evacuated after dismantlement of the sling wires of the 3000 tonf floating crane.
Since the height of the free fallen piles varies because of the irregular seabed during the offshore driving of the sheet piles, the working efficiency was improved by 2-point welding by set of 3 sheet piles to ease driving. The sheet piles were driven in a clockwise sequence after replacing the equipment of the driving barges by vibro-hammers. Driving was done uniformly to prevent the occurrence of insufficiently rooted piles. A series of 3 driving cycles was performed. The first cycle drove the piles down to 2m, the second cycle down to about 2/3 of the embedded length and the third cycle down to the final depth so as achieve uniform and vertical driving of the piles.
The templates were pulled after setting of the 450ton floating crane and fastening of the sling wires. Once the bottom template was hauled up to the position of the top template, the templates were fixed using steel bars. Similarly to the installation of the cells, the templates were fixed by welding of dog plates. The dismantled top and middle templates were conveyed from the offshore site to the shore workshop for reuse.
The driving barge equipment was evacuated from the cell and the conveyor barge was set for the first filling. The cell being vulnerable to the tide and waves, filling was executed within a short period of time using the equipment of the conveyor barge. The crushed stones for filling were dropped at the center of the first cell up to 20% of the total quantity and riprap had to be laid to produce uniform soil pressure in the cell. The quantity of filling was executed to exceed 50% of the design quantities.
Works were then processed similarly to the first filling. Silt protector was also installed to prevent overflow during filling and avoid the occurrence of environmental pollution. The remaining 50% of filling was filled within a short period of time. After completion of filling, the top surface was leveled and arranged. Finally, the arrangement of the pile-cap (EL +4.5m) of the sheet piles was executed.

Figure 7 : In-Filling of Crushed Stones to Resist the Ship-Impact

Figure 8 : Constructions of the Ring Wall and the Cap

4. CONCLUSIONS

Incheon Bridge has 44 large-diameter dolphins around the center span to protect the bridge against the collision with navigation vessels. These dolphins are circular type cell structures and consist of straight-web sheet piles and filling materials.
Cell structures of the dolphin were fabricated in the casting yard, or in the offshore site according to their installation locations. Sheet pile wall was penetrated into the stiff layer below the seabed to support the cellular dolphin. Specified crushed stone were poured into the cell to secure the resistance against the ship-impact.
Construction procedures of the ship-impact protective dolphins were briefly introduced.